Exh 4

Japanese Kokai Patent Application No. Sho 61[1986]-91377

Translated from Japanese by the Ralph McElroy Co., Custom Division
P.O. Box 4828, Austin, Texas 78765 USA

Code: 598-64536
Ref. No.: AM 306-1JP/ETCH/HDP/PJS

EXHIBIT A-4

JAPANESE PATENT OFFICE
PATENT JOURNAL
KOKAI PATENT APPLICATION NO. SHO 61[1986]-91377

| | |
|---|---|
| Int. Cl.$^4$: | C 23 F 1/08<br>C 23 C 16/50 |
| Sequence Nos. for Office Use: | 6793-4K<br>8218-4K |
| Application No.: | Sho 59[1984]-213363 |
| Application Date: | October 12, 1984 |
| Publication Date: | May 9, 1986 |
| No. of Inventions: | 1 (Total of 4 pages) |
| Examination Request: | Not requested |

# SURFACE PROCESSING DEVICE

| | |
|---|---|
| Inventors: | Atsushi Sekiguchi and<br>Hideo Mito<br>c/o Nichiden Aneruba K.K.<br>5-8-1 Yotsuya, Fuchu-shi,<br>Tokyo |
| Applicant: | Nichiden Aneruba K.K.<br>5-8-1 Yotsuya, Fuchu-shi,<br>Tokyo |

Agent: Kenji Murakami

[There are no amendments to this patent.]

Claims

1. Surface processing device characterized by the fact that in a surface processing device which executes a prescribed surface processing utilizing emitted light of a prescribed wavelength, an LTE plasma is generated by flowing a first gas which emits light of a prescribed wavelength through an inductively coupled or capacitively coupled high-frequency power space at a location capable of irradiating the to-be-processed material and/or to-be-processed surface of the to-be-processed material arranged within a processing chamber and said prescribed surface processing is executed with said LTE plasma as the light source.

2. Surface processing device of Claim 1 characterized by the fact that said light source is connected spatially with said processing chamber or is connected via an optically transparent window.

3. Surface processing device of Claim 1 characterized by the fact that a screen-shaped electrode capable of voltage impression which can transmit emitted light between said LTE plasma part and to-be-processed material while shielding or selectively transmitting charged particles was arranged.

## Detailed explanation of the invention

### Industrial application field

The present invention relates to an opto-chemical reaction device which utilizes high-frequency discharge of high-intensity emitted light used for surface processing such as surface modification, photo cleaning, etching, formation of insulating films, metal films, semiconductor films of a semiconductor device, etc.

### Prior art

In the method of activating a gas according to an opto-chemical reaction and depositing a target material on a substrate surface and executing processing such as making the film thin, etching, modifying the surface, etc., there has been rapid progress in recent years due to processing being possible at low temperatures, processing not causing damage from impact of charged particles, processing not available in conventional technology because of opto-chemical selectivity, selection of the reaction process and control of the film formation being easy, etc.

Conventional opto-chemical surface processing devices can be roughly divided into two methods. One method uses a discharge lamp as the light source and the other method uses a laser as the light source. In the method which uses a discharge lamp, the intensity of the emitted light is generally low, and in the method which uses a laser, the laser is expensive.

Also, normally the processing chamber and the light source of the processing device are separated by a window, and in the case of photo CVD, etc. in particular, foreign matter deposits on said window and the emitted light is attenuated. As an invention which improves on this, Patent Application Number Sho 57[1982]-122857 (Kokai Patent Application Number Sho 59[1984]-16966), for invention titled "Chemical Vapor Deposition Device" has been filed. This invention is characterized by the fact that the light source part and the processing part are arranged within the same enclosure, but it is apparent from the explanation in the specifications that hot cathode discharge, AC discharge, or direct current discharge is used as the light source. The content of the constitution for this invention is that stabilization of the discharge, namely, stabilization of the light source, is achieved by feeding a gas that protects the electrode. Consequently, it has the demerit that the device structure becomes complex, and since a gas with no direct relationship to the surface processing is introduced into the processing system, this restricts the type of surface processing and has a negative influence on the processing.

## Objective of the invention

The present invention aims to provide a device which solves said problems and can execute effective processing of good quality without restricting the type of surface processing, and additionally aims to provide a device which does not require feeding a gas to protect the electrode.

Constitution of the invention

The present invention is a device which executes surface processing by providing a light source which uses high-frequency LTE plasma discharge and a processing chamber which executes a prescribed processing by being connected to said light source.

Application examples

An application example of the present invention is shown in Figure 1. (10) is the light source apparatus and (20) is the processing apparatus. The present application example provides light source apparatus (10) and processing apparatus (20) within the same enclosure.

First of all, light source apparatus (10) will be explained. Discharge is generated on the inside part of discharge tube (6) according to high frequency inductive coupling by a high-frequency voltage generated by power source (1) of high frequency (a few kHz to a few hundred MHz) being impressed on coil (2). The gas for the light source is introduced to the inside part of said discharge tube (6) in the direction of gas flow (5) via valve (4). Also, discharge tube (6) is normally constructed of an insulating material, of which quartz glass or ceramic material is effective. When quartz glass is used, there is a concern that the quartz glass will be fused with increase in the temperature of the plasma, so discharge tube (6) may be composed into a double tube of quartz glass with cooling water channeled between the external and internal tubes.

High-frequency glow discharge is generated first of all as the impressed high-frequency power is increased, and when even

greater power is applied, the plasma is pinched hysteretically and LTE (Local Thermal Equilibrium) plasma (3) is generated. The intensity of this plasma is very high and in many cases manifests a spectral pattern which differs from normal direct current glow discharge. For example, in the case of hydrogen discharge, a continuous spectrum, originating in the hydrogen molecules, which extends into the ultraviolet light zone from the visible light zone exists in normal direct current glow discharge or high frequency glow discharge, and in addition to this, emission of the Balmer series and Lyman series originating in the hydrogen atoms can be observed. In this case, however, emission according to hydrogen atoms is relatively weak, thus the color of the emitted light is a purplish white color. However, the color of the emitted light in LTE plasma (3) is a [illegible] color of very high intensity. It is known that this is the result of the intensity of the Balmer series of hydrogen emission becoming very high. The brightness of the Lyman series is also very high, but it does not exist in the visible part simultaneously, so it is not visible to the eye directly. Lyman $\alpha$ light has a wavelength of 121.6 nm, and when light of this wavelength is used, in addition to direct decomposition of silane and disilane becoming possible as is publicly known, there is the merit of being able to use an Al reflector with an $MgF_2$ coating and optical transmission material such as $MgF_2$, LiF, etc. making assembly of an optical system very easy. Conventionally, a light source with the high intensity of this Lyman $\alpha$ light did not exist, so this light was little utilized. The high frequency LTE plasma light source of the present invention noted above satisfies this point. As the gas for said light source, gases such as argon, helium, hydrogen, etc. and mixtures thereof are as useful as hydrogen.

Differentiation between high-frequency glow discharge and high-frequency LTE plasma discharge is very easy since clear differences exist such as:

(a) There is a tendency for the emission to expand greatly in high-frequency glow discharge, and there is a tendency for the emission to be pinched in the high-frequency LTE plasma discharge.

(b) Light emissions in the two discharge processes differ in the spectral pattern in many of the gases used for the light source. According to this spectrum, in addition to the difference in the electron state, vibration and rotation mode excitation are often observed in the high-frequency LTE plasma discharge when compared to the high-frequency glow discharge if the gas for the light source is a polyatomic molecule.

(c) The high-frequency glow discharge state and the high-frequency LTE plasma discharge state often have hysteretic transition with the discharge power, discharge pressure, etc. as parameters and the discharge impedance differ greatly between the two discharges.

(d) The intensity is very high in the high-frequency LTE plasma discharge.

Also, in light source gases such as helium, etc., discharge impedance does not change hysteretically so differentiating high-frequency glow discharge and high-frequency LTE plasma discharge solely from impedance is difficult, but there is a tendency for the plasma to be pinched in the high-frequency LTE plasma discharge state and the two discharges can be differentiated visually.

Next, processing apparatus (20) will be explained. Processing apparatus (20) is comprised of processing chamber (7) capable of being maintained airtight if necessary, injection ring (13) which injects a reaction gas, and substrate holder (8) for installing substrate (16), and it has a structure in which light (17) emitted from LTE plasma (3) irradiates the inside of processing chamber (7). A prescribed reaction gas is introduced to injection ring (13) in flow direction (12) via valve (11) and fed to into processing chamber (7) by injection ring (13). Temperature controller (9) is installed in substrate holder (8) and can adjust the temperature of the substrate according to necessity.

Said reaction gas and said gas for the light source are exhausted in the direction of gas flow (15) via valve (14).

It is possible to discharge said gas for the light source in exhaust direction (21) between light source apparatus (10) and processing apparatus (20) as shown in Figure 2.

It is possible to create an a - Si : H film of good quality on substrate (16) using the device shown in Figure 2 by using hydrogen as the gas for the light source and silane as the reaction gas. Also, it is possible to create an SiN film of good quality using the device shown in Figure 1 by using ammonia as the gas for the light source and silane as the reaction gas. The mechanism for the reaction is not clear in this case, but it is considered to be due to emission of Lyman $\alpha$ light of hydrogen atoms generated from the LTE plasma of ammonia. While silane is decomposed by this light, nitrogen radicals generated by LTE plasma are fed as the nitrogen source.

In Figure 1 and Figure 2, light source apparatus (10) and processing apparatus (20) are arranged within the same enclosure

without any object being interposed. This constitution basically eliminates the clouding of the optical window (optical glass window) which was a major problem conventionally when executing surface processing such as photo CVD, etc., and is very useful from this point of view. Also, the constitution of the present invention does not require introducing a gas to protect the electrode since high-frequency discharge is used, and introducing even the high-frequency electrode itself within the enclosure is not necessary. Consequently, stability of intensity, which is a very important factor for the light source, is good, and the device of the present invention has a structure suitable for a surface processing testing device and even for a mass production device.

If light source apparatus (10) and processing apparatus (20) are arranged within the same enclosure, the glow plasma expands at the periphery of the high-frequency LTE plasma discharge in areas with pressure below a few Torr, and the glow plasma often expands even into the processing chamber in areas where the pressure is low. In order to prevent this, a screen, etc. for plasma shielding may be installed between light source apparatus (10) and processing apparatus (20) to prevent the expansion of the glow plasma.

A device with a structure which separates light source apparatus (10) and processing apparatus (20) with an optical window (22) is shown in Figure 3. In this case, clouding of optical window (22) poses a problem in processing such as photo CVD, etc. but this poses no problem during processing such as photo etching, photo cleaning, etc., and the merit of said light source gas not flowing into the processing chamber can be put to

effect. There are cases of not needing to introduce said reaction gas in photo cleaning, etc.

The aforementioned application example is an example which created LTE plasma according to the high-frequency inductive coupling type but LTE plasma can also be created according to the high-frequency capacitive coupling type and even with this a useful device similar to the above can be obtained. These application examples do not have restrictive meaning and many modifications such as improvements, combinations, common use of existing technologies, etc. which uphold the essence of this invention are possible in the surface processing device of the present invention.

Effect of the invention

The present invention is as explained above and can obtain stabilized emitted light in high intensity by using a light source which used high-frequency LTE plasma discharge. The contribution of the device in the present invention in manufacturing semiconductor devices such as surface modification, photo cleaning, dry etching, film formation such as insulation film, metal film, semiconductor film, etc. is considerable and a claim can be made that it is an invention with industrial value.

<u>Brief explanation of the figures</u>

Figure 1, Figure 2, and Figure 3 are frontal cross-section views for the application examples of the device in the present invention.

(10) light source apparatus

(20) processing apparatus

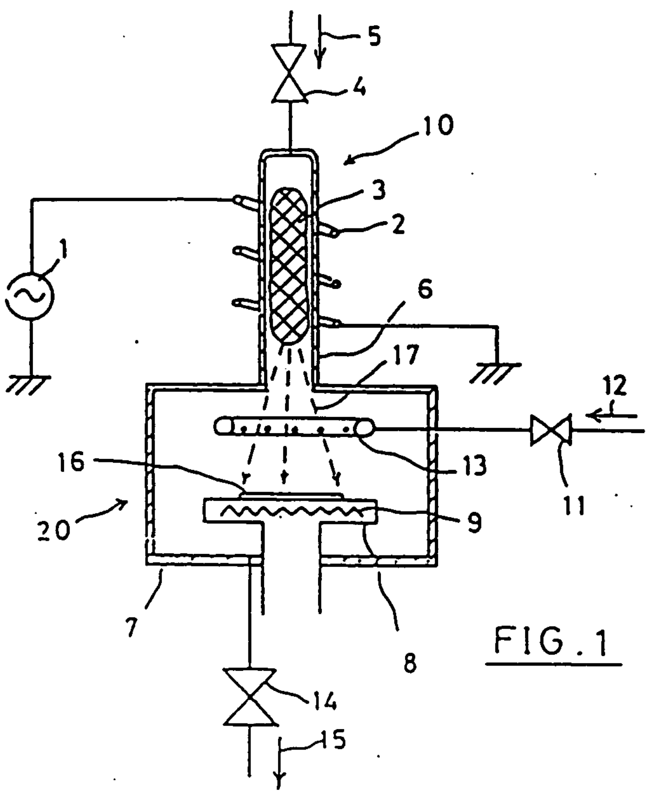


FIG.1

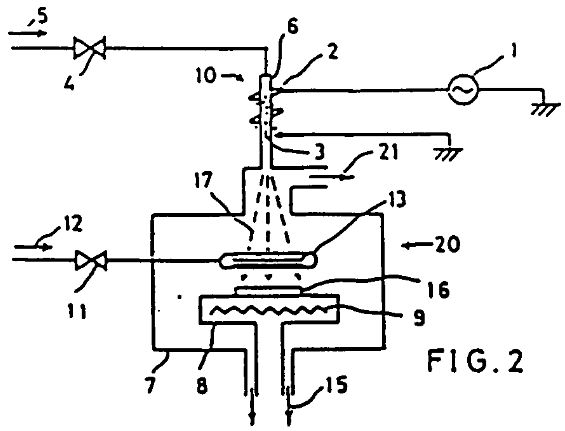


FIG.2

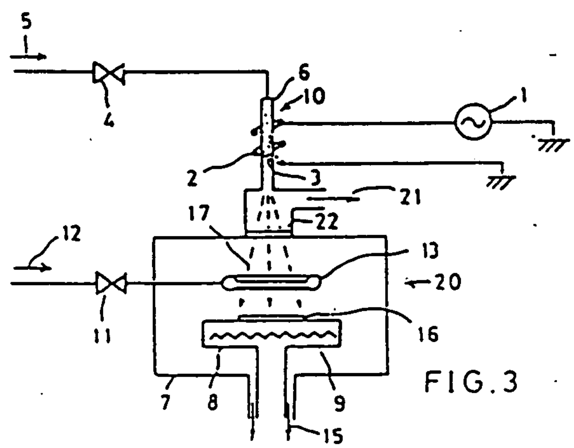


FIG.3